International Journal of Advanced Engineering, Management and Science (IJAEMS)
Peer-Reviewed Journal
ISSN: 2454-1311 | Vol-10, Issue-3; Mar-Apr, 2024
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.103.8

# To design a controller for the solar power Inverter to nullifying the temperature effect

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Received: 08 Mar 2024; Received in revised form: 10 Apr 2024; Accepted: 17 Apr 2024; Available online: 23 Apr 2024

***Abstract*—*The output waveform of sine triangle pulse width modulation at different modulation index is a crisp waveform. This waveform can be completed by adding another waveform. It is called a clamp waveform. This concept is called C to C concept or clipper clamper concept. The single-phase controller circuit is shown below. According to this circuit, anti-parallel diodes with constant DC supply connect to the grid supply. The extension of this circuit i.e. the 3-φ clamper circuit has been shown in The output of controller circuit is added up with NPC inverter.***

***Keywords*— Pulse Width Modulation, Neutral Point Clamp, Controller.**

## I. INTRODUCTİON

In the past ten years, power electronic inverters with high efficiency/high power density performance have gained more and more attention in a variety of home and commercial applications, including motor drives, grid-connected photovoltaic systems, and electric vehicles [1], [2]. The most crucial elements for these kinds of converters to have good final outcome are decreased voltage stress across the power electronic switches, enhanced modulation, and decreased/mitigated values of the high frequency common-mode voltage (HF-CMV) and leakage current [2]. By lowering the weight and dimensions of the output filters in grid-connected inverters, removing or detaching the galvanic transformer and increasing the number of inverter output voltage levels can also aid in the achievement of a high power density design [3]. In light of the aforementioned, transformer-less grid-tied photovoltaic systems are regarded as an effective, small, and well-liked option in recent years, which has led to the widespread release of numerous commercialized versions of recently created inverters [4], [5].

Pulse-dropping occurs when the inverter operates in an over-modulation (OM) area in order to maximize the DC bus voltage (VDC). Numerous researches claim that 1.154 VDC is the greatest DC bus voltage that can be used without pulse-dropping. THD decreases as a result of lower order harmonics appearing in the output waveform as a result of the inverter operating in the over-modulation area. An apparatus called a clamper circuit has been developed to reduce such harmonics. Thus, the methodology for this paper work incorporates the following: reduction of lower order harmonics in the total output waveform in the over-modulation zone.

## II. OPERATİNG PRİNCİPLE

Over-modulation (OM) can be defined in terms of modulation index k.

$$k = \frac{V_{RN}}{V_{mpt}} \qquad (1)$$

It can be similar with transformer turn ratio in our case its value more than one.

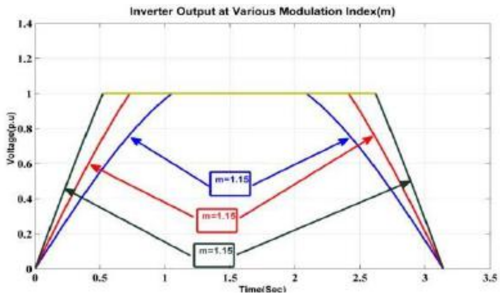


*Fig.1. Voltage waveform (in PU) at different modulation indexes (k>1)*

In Fig. 1, if the k is more than 1, then the clipping waveform appears so pulse dropping increases (as shown in fig. 2). Therefore, the switching of each switch get reduces (fig. 2).

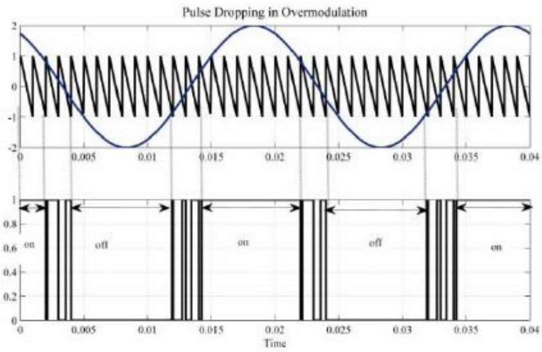


*Fig.2. Pulse failure in R phases*

In fig. 2, the arrow region shows R-phase waveform (i.e., pulse failure). The upper switches device will be continuously switched on. Similarly, on the next pulse dropping, it is continuously off here. Therefore, there are no pulses (pulse failure) at the on and off region; it is well known as pulse failure.

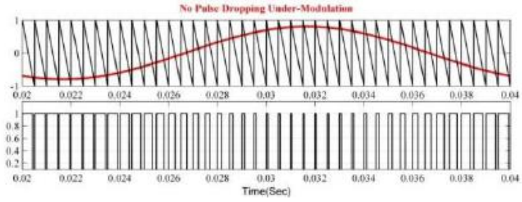


*Fig.3. No pulse failure in under-modulation(UM)*

By comparing fig. 2 and 3, the pulse failure in under and over modulation is shown. By increasing in k (modulation indexes) pulse dropping increase get increases.

### 2.1 C to C Concept

The output waveform of sine triangle pulse width modulation at different modulation index (shown in Figure. 1) is a crisp waveform. This waveform can be completed by adding another waveform. It is called a clamp waveform. This concept is called C to C concept or clipper clamper concept.

The single-phase controller circuit (Fig.: 4(a)) is shown below. According to this circuit, anti-parallel diodes with constant DC supply connect to the grid supply. The extension of this circuit i.e. the 3-φ clamper circuit has been shown in Fig. 4(b). The output of controller circuit is added up with NPC inverter.

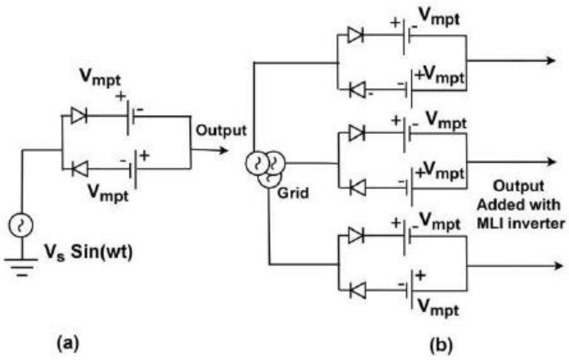


*Fig.4. (a)* 1-φ *(b)* 3-φ *clamped circuits*

### 2.2 Mathematical Modelling of the Controller and NPC convertor

The affiliated Mathematical modeling of the controller and NPC converter is based on C to C concept (i.e. clipper-clamper concept). The mathematical equations of this NPC convertor waveform has been written by equation 2. Similarly, the controller circuit wave-form at the same modulation indexes (k) has shown in equation 3 (by considering k>1) i.e. NPC convertor output wave-form

$$F(x) = \{k\,sin\;wt, \quad 0 < wt \le \sin^{-1}\frac{1}{k} \quad 1 \quad ,\sin^{-1}\frac{1}{k} \le wt \le 180 - \sin^{-1}\frac{1}{k}$$

$$k\;sin\;wt \;\;, 180 - \sin^{-1}\frac{1}{k} \le wt \le 180 \;\} \qquad (2)$$

And controller output wave-form is

$$F(x) = \{0 \;, \quad 0 < wt \le \sin^{-1}\frac{1}{k} \qquad f(x) = k\,sin\,wt \;-\; 1 \quad ,\sin^{-1}\frac{1}{k} \le wt \le 180 - \sin^{-1}\frac{1}{k} \le wt \le 180\,, f(x) =$$

$$0, 180 - \sin^{-1}\tfrac{1}{k} \le wt \le 180 \; \} \qquad (3)$$

For harmonic analysis of these we note that the resultant is eventually equations (Eq. 2 and 3) are converted into the frequency (w) domain by using Fourier series in order to obtain the Fourier coefficient, [20] it has been represent in equation no.4.

$$= \frac{2}{180}\left(\int_0^{\frac{1}{k}} k \sin(x) * \sin \sin \frac{n*180*x}{180} * dx + \int_{\frac{1}{k}}^{180-\frac{1}{k}} 1 * \sin \frac{n*180*x}{180} * dx + \int_{180-\frac{1}{k}}^{180} k \sin(x) * \sin \frac{n*180*x}{18055} * dx\right.$$

$$= \frac{2}{18055}\left(\int_0^{\frac{1}{k}} k\sin(x) * \sin(nx) * dx + \int_{\frac{1}{k}}^{180-\frac{1}{k}} 1 * \sin(nx) * dx + \int_{180-\frac{1}{k}}^{180} k * \sin(x) * \sin(nx) * dx \qquad (4)\right.$$

**2.2.1 NPC converter output:**

By using eq. 4 harmonics spectra of each part of the inverter has been shown by eq. 5 to 7.

$$\frac{2}{180}\int_0^{\left(\frac{1}{k}\right)} k\sin(x) * (\sin(n.x))\, dx = \frac{2k*\sin\left(n\left(\frac{1}{k}\right)\right)\sqrt{\frac{k^2-1}{k^2}} - n\cos\left(n\left(\frac{1}{k}\right)\right)}{180(n^2-1)} \qquad (5)$$

$$\frac{2}{180}\int_{\left(\frac{1}{k}\right)}^{180-\left(\frac{1}{k}\right)} 1 * \sin(n.x)\, dx = \frac{180 * \cos\left(n\left(\frac{1}{k}\right)\right) - \cos\left(n\left(-180+\left(\frac{1}{k}\right)\right)\right)}{2n} \qquad (6)$$

$$\frac{2}{180}\int_{180-\left(\frac{1}{k}\right)}^{180} k\sin(x) * (\sin(n.x))dx = \frac{2}{180(n^2-1)}\left(k\left(\frac{1}{2}\sin\left((n-1)\left(\left(\frac{1}{k}\right)\right)\right)n + \frac{1}{2}\sin\left((n-1)\left(\left(\frac{1}{k}\right)\right)\right) - \frac{1}{2}\sin\left((n+1)\left(-180+\left(\frac{1}{k}\right)\right)\right)n + \frac{1}{2}\sin\left((n+1)\left(-180+\left(\frac{1}{k}\right)\right)\right) + \frac{1}{2}(n-1)180) + \frac{1}{2}\sin\,(n-1)180 - \frac{1}{2}\sin\,(n(n+1)180) + \frac{1}{2}\sin(n-1)\right)\right) \qquad (7)$$

Similarly, for the controller

$$b_n^{\prime} = \frac{2}{180}\int_0^{180} f'(x) * \sin \frac{n*180*x}{180} * dx$$

$$= \frac{2}{180}\left(\int_0^{\frac{1}{k}} 0 * \sin \frac{n*180*x}{180} * dx + \int_{\frac{1}{k}}^{180-\frac{1}{k}} (\sin(x) - 1) * \sin \frac{n*180*x}{180} * dx + \int_{180-\frac{1}{k}}^{180} 0 * \sin \frac{n*180*x}{180} * dx\right)$$

$$= \frac{2}{180}\left(0 + \int_{\frac{1}{k}}^{180-\frac{1}{k}} (k * \sin(x) - 1) * \sin(nx) * dx + 0\right) \qquad (8)$$

**2.2.2 Controller output:**

By using Eq. 8 Fourier transform of an active filter output (as shown by Eq. 9).

$$\frac{2}{180}\int_{\left(\frac{1}{k}\right)}^{\left(\frac{1}{k}\right)} (k\sin(x) - 1) * \sin(n.x)\, dx = \frac{2}{n(n^2-1)180}\left(1\left(\frac{-1}{2}\left((n-1)\left(-180+\left(\frac{1}{k}\right)\right)\right)n^2 + \frac{1}{2}k\sin\left((n+1)\left(-180+\left(\frac{1}{k}\right)\right)\right)n^2 + \cos\left(n\left(\left(\frac{1}{k}\right)\right)\right)n^2 - \frac{1}{2}k\sin\left((n-1)\left(-180+\left(\frac{1}{k}\right)\right)\right) n - n.k\sin\left(\left(\frac{1}{k}\right)\right)\sqrt{\frac{k^2-1}{k^2}} - \frac{1}{2}k\sin\left((n+\right.\right.\right.$$

$$1)\left(-180+\left(\frac{1}{k}\right)\right)\bigg)n - cos\left(n\left(-180+\left(\frac{1}{k}\right)\right)\right) + cos\left(n\left(\frac{1}{k}\right)\right)\bigg)\bigg) \quad (9)$$

all electrical quantities are in per unit.

### 2.3 Boundaries and Limitations

Some boundaries and limitations are identified at the time of study and some assumptions have been considered for accomplishment of the work.

- Forward voltage drop of diode is not considered because the DC input voltage is higher; therefore, it can be neglected.
- DC ripple voltage effect is assumed to be zero due to filtering circuit.
- The delayed time is neglected.
- Turn on voltage drop and turn off leakage current is neglected.
- The load has sufficient reactive power to support identical voltage and current waveform.
- Grid supply (used by Controller) should have a very low THD.

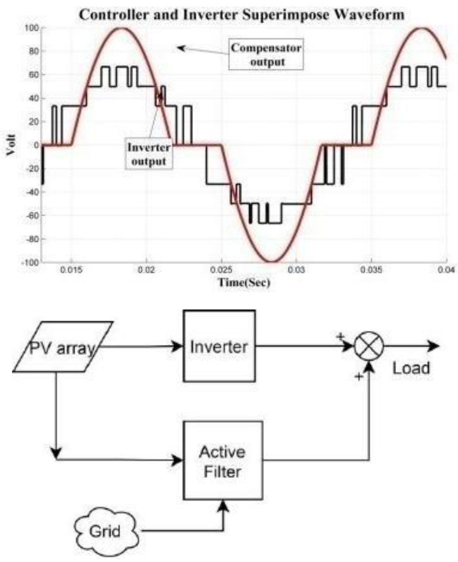


*Fig. 6. (a)Super-impose controller and NPC convertor (b) Block diagram of the complete system*

## III. RESULTS

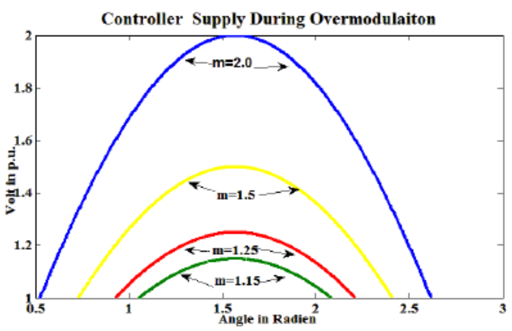


*Fig.5 Controller output wave-form at different modulation indexes(k)*

The output waveform of a 1-φ clamper circuit with the same modulating indexes is shown in Fig. 5. The modulation index (K) depends on the peak value of the carrier wave and the DC voltage. Suppose due to an increase in temperature, the PV array output voltage reduces [6], it results into modulating index increase from 1.15 to 2, and then the output of the controller is also changed shown in Fig. 5.

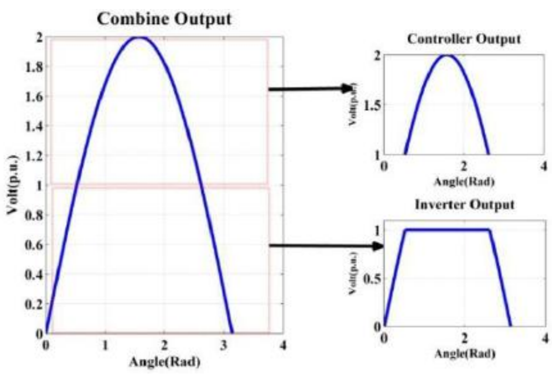


*Fig.7. Controller and NPC converter*

## IV. CONCLUSİONS

The controller supply opposite polarity harmonics (with respect to the NPC converter), and after merger this, we can nullify the over-all total harmonic distortion. Increment in modulation index also reduces the fundamental voltage so controller also supply the additional fundamental supply.

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